

Method for designing drop-of-wire recognition systems on sections of undistorted two-wire power transmission lines

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Abstract. In this work a general statement of the problem of designing distributive electrical systems that recognize breakage of wires on sections of power lines using a multifunctional wire with an isolated residential wire is formulated. The use of overhead wires with the proposed construction of the housing will make it possible to solve many electrical problems very easily and cheaply without the use of expensive equipment. The correspondence table of the information current values of the power supply unit I_0 and of the wire breakdowns on the sections in the two-wire transmission line is obtained by simulation. The proposed method of diagnostics and monitoring of the state of power lines is not expensive and allows the maintenance staff, being at the substation, to detect rapidly and remotely the breakage of wires on the parts of the network and the distance to it. In order to ensure that the repair crew is sent to the exact location of the damage, this will improve the reliability of the electrical supply to consumers. This is achieved by the fact that the information wire has an independent power supply and thus allows for control of the network at any time.

1. Introduction

Long-distance overhead circuit are the least reliable part of the power grid. The statistics show that in the networks of its voltage the annual amount of damage is calculated by the hundreds, and in subscription networks it feeds by the thousands. Most of the damage to the air lines consists of short circuits and cliffs. Both natural and artificial conditions can be the cause. At the same time, fault location (FL) and restoring damaged parts of the power grid are the most complex and lengthy technological operations.

This problem is particularly acute for 6–35 kV power lines. Difficulties arise from the use of insulated neutrality in electrical distribution networks, as well as their branched tree topology. Therefore, the diagnostic methods successfully used for 110 kV and higher lines with a closed ground neutral are not applicable.



The main requirement under FL in electrical networks is to restore power to disconnected power collectors as quickly as possible while minimizing labor, time and search costs. There is therefore a need for an effective system of rapid diagnosis and continuous monitoring from the standstill of the electrical networks, coupled with timely preventive repair of the lines, which will reduce the number of accidents and the time of the FL and therefore, a reduction in financial losses due to the lack of electricity to consumers.

The analysis of information from the Soviet-Russian and foreign technical literature showed that the problem of rapid diagnosis of the state of distribution electrical networks in Russia, in the CIS countries and abroad has not been completely solved [1–4]. The variety of types and characteristics of damage has not yet made it possible to find any universal diagnostic method that is equally successful in detecting short circuits and breakage of power lines and other faults. The lack of advanced remote FL techniques using the latest advances in science and technology makes it difficult to detect quickly damage to transmission lines. Therefore, the development of an effective method for diagnosing and monitoring the status of electrical distribution lines by voltage is relevant.

The need to develop systems for detecting power breakdowns through difficult and inaccessible mountain ranges is heightened by the difficulty of visually monitoring breakdowns.

In this work:

- The generalized problem of designing distributive electrical systems that recognize breakage of wires in sections of complex power lines using a multifunctional wire with an isolated residential wire is formulated [5].
- The special problem of detection of breakage of cables for long-distance two-wire transmission lines is considered.

2. Formulation of the generalized problem of designing distributed electrical systems that recognize breakage of wires in sections of complex power lines using a multifunctional wire

A multifunctional wire with an isolated living area. In work [5] a multifunctional wire with an isolated housing (Figure 1) was proposed, the use of which makes it possible to:

- to detect breakages in power lines;
- to discover the location of the closure in the line;
- to detect the appearance of an alternating electric arc;
- determine the load value (electric current) of the line without its rupture and analyse the electrical energy transmission mode using a new method of measuring electric current [6];
- if necessary, it is easy to determine the current line resistance value and the wire temperature, and to assess the contact conditions at the connection point of the wires to the line, etc., i.e. the use of wires and cables with the proposed construction of the housing will make it very easy and cheap to solve many electrical problems without the use of expensive equipment.

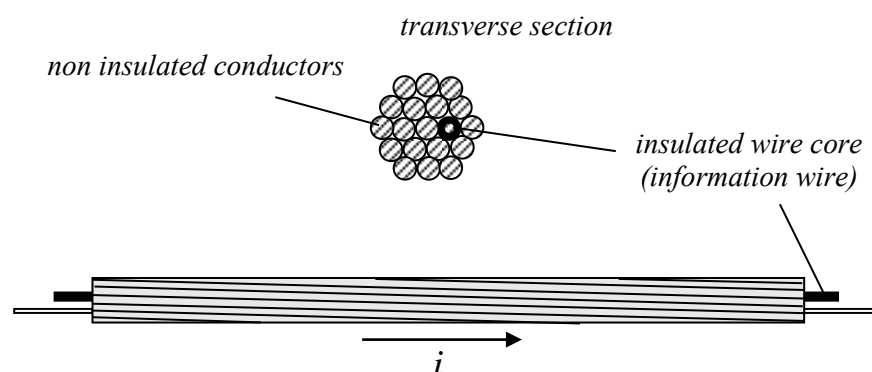


Figure 1. Construction of a multifunctional wire with enclosed housing.

In this work, a multifunctional wire consisting of two components (Figure 1):

- a power wire for the transmission of electrical energy from power supply units to load units;
- a cable housing insulated from a power wire is used for the realization of electrical distribution systems (Figure 2) which recognize breakage of wires on sections of transmission lines because the wire has that property, when the power line is broken, the information is cut off.

The distribution electrical network structure is the initial information for the design of electrical distribution systems that recognize breakage of cables in the power lines. Let the electrical distribution network analyzed consist of a plurality of n -wire sections connected by corresponding units and have an open structure. The state of each section of the network (i_1, i_2) , connecting the nodes i_1 and i_2 , is characterized by a variable $x_{i_1, i_2} \in \{0, I_{i_1, i_2}\}$, where $x_{i_1, i_2} = 0$ – cut; $x_{i_1, i_2} = I_{i_1, i_2}$ – there is no drop; I_{i_1, i_2} – current of the section of the network (i_1, i_2) .

The aim of the design is to develop such schemes for connecting the information wires of the network sections and for connecting the information wires in the power supply units to the DC voltage U_0 (cf. Figure 2), at which the values of the information currents $I_0^1, I_0^2, \dots, I_0^n$, which are functions of the state x_{i_1, i_2} of all sections i_1, i_2 of the network, would unambiguously reflect the breakage of the cables of the respective sections.

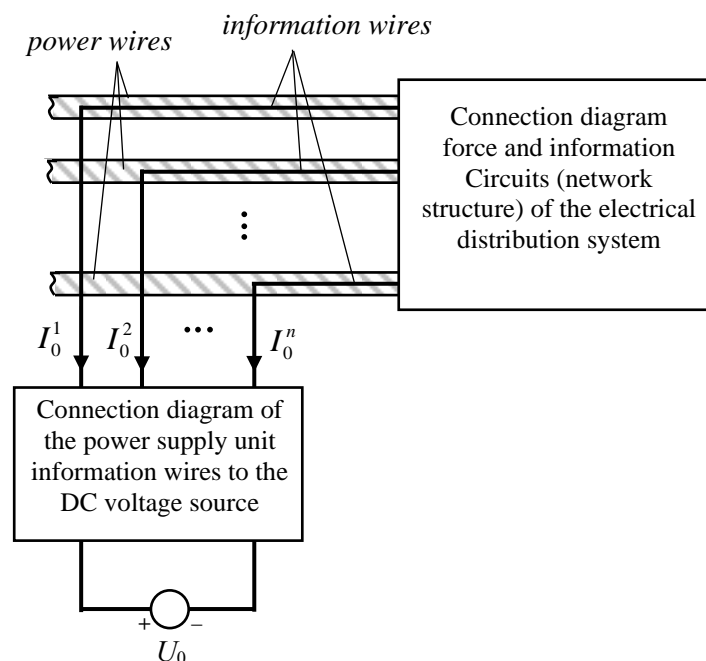


Figure 2. Electrical distribution system structure.

3. Method for detecting wire breaches in two-wire transmission lines

Figure 3 a shows the connection of the power and information cables of the two-wire sections of the power lines, and Figure 3b is a principle scheme of substitution of information wires. Between the phases of the information wires, at a certain distance, adjustable resistances are installed, through which the electric current flows. Between the phases of the information wires, at a certain distance, adjustable resistances R_1, R_2, \dots, R_k are installed, through which the electric current flows ΔI . In the event of a break in the wire in some area i_1, i_2 of the network, the information current in the power supply unit I_0 will be reduced by an appropriate amount, which will make it possible to quickly and remotely determine the part of the network where the break occurred.

Algorithm for calculating network parameters.

At the given values: DC voltage $-U_0$, V; wire lengths – l , km; internal resistance on sections of the information wire $-R_{01} = R_{12} = \dots = R_{k-1,k}$, Om/km; currents flowing through adjustable resistors – $I_1 = I_2 = \dots = I_k = \Delta I$, mA, need to determine the value of adjustable resistances – in order to ensure that the currents flowing through them are the same and equal ΔI , thus making it possible to uniquely determine the breakdowns of the wires in the parts of the transmission lines.

The information current of the power I_0 and current unit on each section of the line $I_{12}, I_{23}, \dots, I_{k-1,k}$ according to Kirchhoff's Law I will be equal to:

$$I_0 = \Delta I + \Delta I + \dots + \Delta I = k \cdot \Delta I,$$

$$I_{12} = I_0 - \Delta I, I_{23} = I_{12} - \Delta I, \dots, I_{k-1,k} = I_{k-1} - \Delta I.$$

Make up the Kirchhoff Law II equation for the 1st contour: $2R_{01}I_0 + R_1\Delta I = U_0$, hence

$$R_1 = \frac{U_0 - 2R_{01}I_0}{\Delta I},$$

for the 2nd contour: $2R_{k-1,k}I_{k-1,k} + R_k\Delta I - R_{k-1}\Delta I = 0$, hence

$$R_2 = \frac{R_1\Delta I - 2R_{12}I_{12}}{\Delta I},$$

etc., for k -th contour: $2R_{k-1,k}I_{k-1,k} + R_k\Delta I - R_{k-1}\Delta I = 0$, hence

$$R_k = \frac{R_{k-1}\Delta I - 2R_{k-1,k}I_{k-1,k}}{\Delta I}.$$

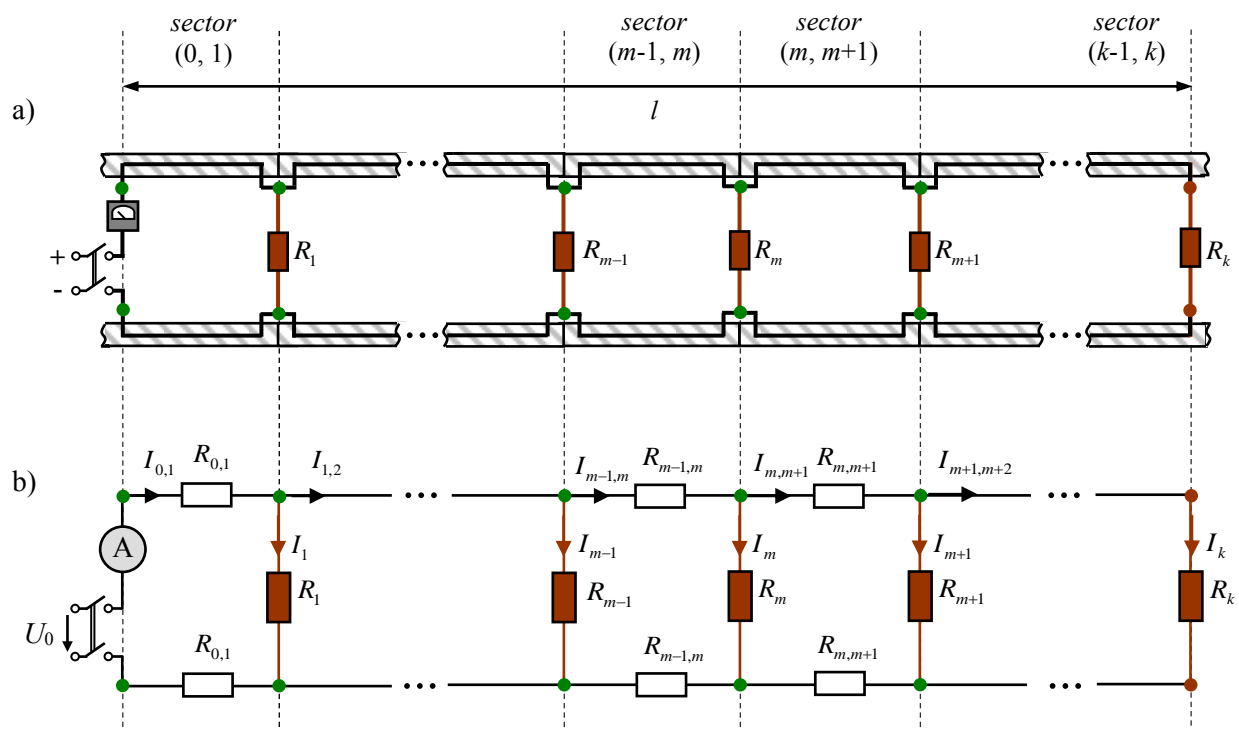


Figure 3. Connection diagram of power and information wires of two-wire sections of power lines (a), principle diagram of connection of information wires (b).

4. Simulation of the process of detection of breakage of wires at sites in a two-wire transmission line

Using the example of a two-wire transmission line with a length of 5 km, with parameters $U_0 = 220 \text{ V}$; $R_{01} = R_{12} = \dots = R_{k-1,k} = 13 \text{ Ohm/km}$, by simulating the breakage process (the breakage of the wire in Figure 4 is simulated by switching devices), the correspondence table of the information current of the power unit I_0 and the breakup of the wire in Sections 1–5 is obtained.

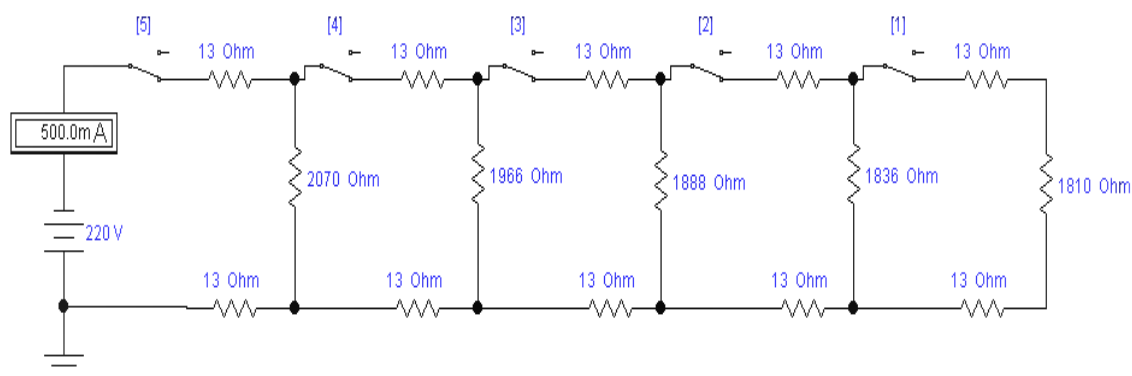


Figure 4. Simulation of the winding process in two-wire power transmission lines.

Modeling was done using Electronics Workbench. It can be seen from the table that at the current value of $I_0 = 412 \text{ mA}$ the breakage occurred at the site 1, at the current value of $I_0 = 315 \text{ mA}$ the breakage at the site 2, etc.

Table 1. Key correlation of the power station information current value I_0 and the wire breakage value of the network areas.

	No break	Cliff on the site				
		1	2	3	4	5
Milliammeter reading	500	412	315	211	105	0

5. Conclusion

In that work:

- defines the general definition of the task of designing distributive electrical systems that recognize breakage of wires on sections of power lines;
- the special problem of designing a distribution electrical system that detects breakage of wires in sections in a two-wire transmission line is considered;
- the results of the simulation are a table of the information current values of the power unit I_0 and the lines of the sections in the two-wire transmission line.

Thus, an efficient method for diagnosing and monitoring the state of electrical distribution lines has been developed, which is low-cost and allows service personnel to be at the substation, Rapidly and remotely detect the breakage of wires in the power lines and the distance to it, so that the repair crew can be directed exactly to the damaged area, thus improving the reliability of the power supply to consumers.

Besides, at «fan» disconnections, which takes place in our republic when the power wire is out, in rural areas wires of the network are often stolen, and the use of this method of detection of breakdowns of the network sections, will allow for quick reaction and prevention of such theft, because the information wire has an independent power supply and thus allows to control the network at any time.

It should be noted that the increase in the number of diagnosed sites, as can be seen from the above methodology, increases the value of the information current I_0 , which may exceed the permissible value of I_{\max} . To overcome this problem, the breakage detection system should be split into separate stand-alone subsystems, and the information should be transferred to the dispatching office via digital communication channels.

Further development. The considered method of detection of breakage of wires in sections in two-wire transmission lines can also be generalized for complex n-wire branched distribution electrical systems.

References

- [1] Salehi M and Namdari F 2018 Fault location on branched networks using mathematical morphology *Generation Transmission & Distribution IET* vol **12** pp 207–16
- [2] Ananthan S N, Padmanabhan R, Meyur R, Mallikarjuna B, Reddy M J and Mohanta D K 2016 Real-time fault analysis of transmission lines using wavelet multi-resolution analysis based frequency-domain approach *Science Measurement & Technology IET* vol **10** pp 693–703
- [3] Bains T P, Sidhu T S, Xu Z, Voloh I and Dadash Zadeh M R 2018 Impedance-Based Fault Location Algorithm for Ground Faults in Series-Capacitor-Compensated Transmission Lines *IEEE Transactions on Power Delivery* vol **33** pp 189–99
- [4] Minulin R G, Petrushenko Y Y and Fardiyev I S 2007 Lokatsionnaya diagnostika linii elektroperedach. IX Simpozium 'Elektrotehnika 2030' Rossiyskaya Federatsiya
- [5] Satarkulov K A, Asanova S M and et al 2009 Tokoprovodyashchaya zhila provodov i kabeley Patent KG no 1187
- [6] Satarkulov K A and et al 2008 Sposob izmereniya elektricheskogo toka v provodakh liniy elektroperedach Patent KG no 596